Renewable and Sustainable Energy Reviews 31 (2014) 194–201

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Energy crisis and potential of solar energy in Pakistan

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ARTICLE INFO

Article history:
Received 28 August 2013
Received in revised form
27 October 2013
Accepted 13 November 2013
Available online 14 December 2013

Keywords:
Energy crisis
Renewable Energy
Solar Energy

ABSTRACT

Energy is the basic need of modern life. Pakistan is an energy deficient country. Energy crisis is making bad impacts and destroying the economy. The current study investigates the relationship between the energy and demand supply in Pakistan. The purpose of this research is to evaluate the real reasons behind the current energy crisis. We want to find supplementary and alternate energy sources to cut down the load on the national energy mix. We select different areas and conduct our research and find the best possible renewable energy sources. In this paper we proposed the solution and best available indigenous resource in energy demanding areas.

Contents

1. Introduction

Increasing consumption and demand for energy shows that energy will be one of the major problems in the world [1]. Alternative and renewable resources of electrical energy are required to jam-pack this demand. Pakistan is facing an energy deficiency, and most of the northern areas are still not electrified. Energy supply and demand gap is very large. Due to an energy shortfall urban areas are facing 10–12 hours load shedding while in rural areas electricity remains unavailable for 16–18 hours [9,13]. Some indigenous source like hydro-power and thermal power are in progress and not sufficient to overcome the energy shortfall. Pakistan has limited fossil fuel resources and needs to import fossil fuel. But the poor economy does not allow importing fossil fuel on a large scale. Pakistan is situated in the utmost solar isolation area in the Earth [6]. To overcome the energy shortfall in Pakistan it is necessary to expand native energy resources like hydropower, solar and wind.

The potential of renewable energy resources can be used to electrify the off-grid areas in the western deserts and northern regions. Instead of electricity produced, solar energy also has some applications such as solar cookers and solar water heaters [7]. In addition, this study describes the role of R&D institutions of Pakistan to defeat this issue and promote solar energy technologies. Utilization of this economical renewable energy source requires some significant efforts.

European Union (EU) has made the new rule that being a member of EU each country should produce at least 22.1% of their energy from best alternative energy sources. Pakistan can also fulfill its need by following this rule and can be an environmentally friendly nation.

2. Geography of Pakistan

Latitudes and longitudes of Pakistan are 24° to 27°N and 61° to 76° E respectively. It is divided in 5 provinces namely Khyber

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1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.11.023

Pukhtoon kha (KPK), Punjab, Baluchistan, Sind and Gilgit Baltistan. Some major areas and cities are shown in Fig. 1.

3. Real reasons

In Pakistan during the last ten year period energy demand has increased significantly, since policy failures supply has failed to match this augmentation [10]. The energy sector has been in swearing condition for many years. A main organization water and power development authority (WAPDA) was established in 1967 to deal with the power sector, it serves 88% electricity consumers of Pakistan [13]. Development of water and hydro-power resources is the main objective of WAPDA (Fig. 2). To fulfill the energy demands of the country that the department has an ambitious plan; Vision 2025 (divided in three phases). Under this plan total a of 23 hydro-power projects would be completed. But unfortunately some major projects are not completed till 2012 due to financial and political reasons (Figs. 2–15).

WAPDA was restructured in 2007 to remove inefficiencies and overcome the energy crisis. Now the process of distribution of electricity is divided into ten distribution companies (DISCOs). For the generation of electricity Four Generation companies (GENCOs) are working. Look after of 220 KV and 500 KV transmission lines and grid stations owned by the WAPDA are the responsibility of National Transmission and Dispatch Company (NTDC). WAPDA still controls thermal generation and hydropower development. While Pakistan electric power company (PEPCO) is managing the transition of WAPDA to corporate structure and promoting IPPs.

Private power and infrastructure board (PPIB) was established in 1994 after the extension in ministry of water and power. Independent power producers were introduced in this power policy to enhance the generation capacity and in 2002 policy further incentive was offered to the power sector [12]. A drawback of this policy is as most of the independent power plants run on furnace oil and only a limited number of plants operated on

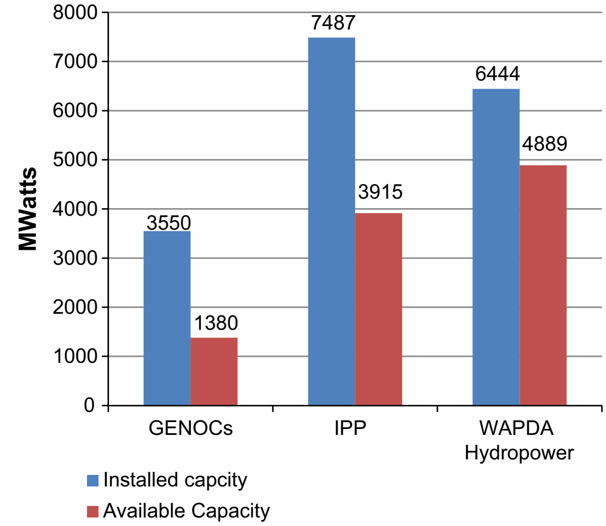


Fig. 2. Power generation by various sectors.

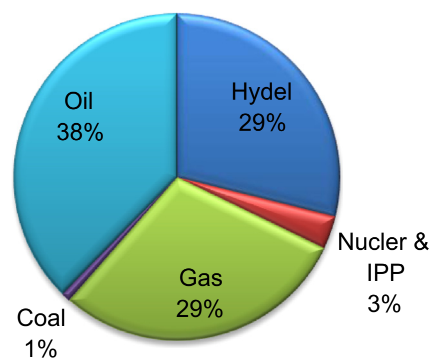


Fig. 3. Energy production by renewable resources.

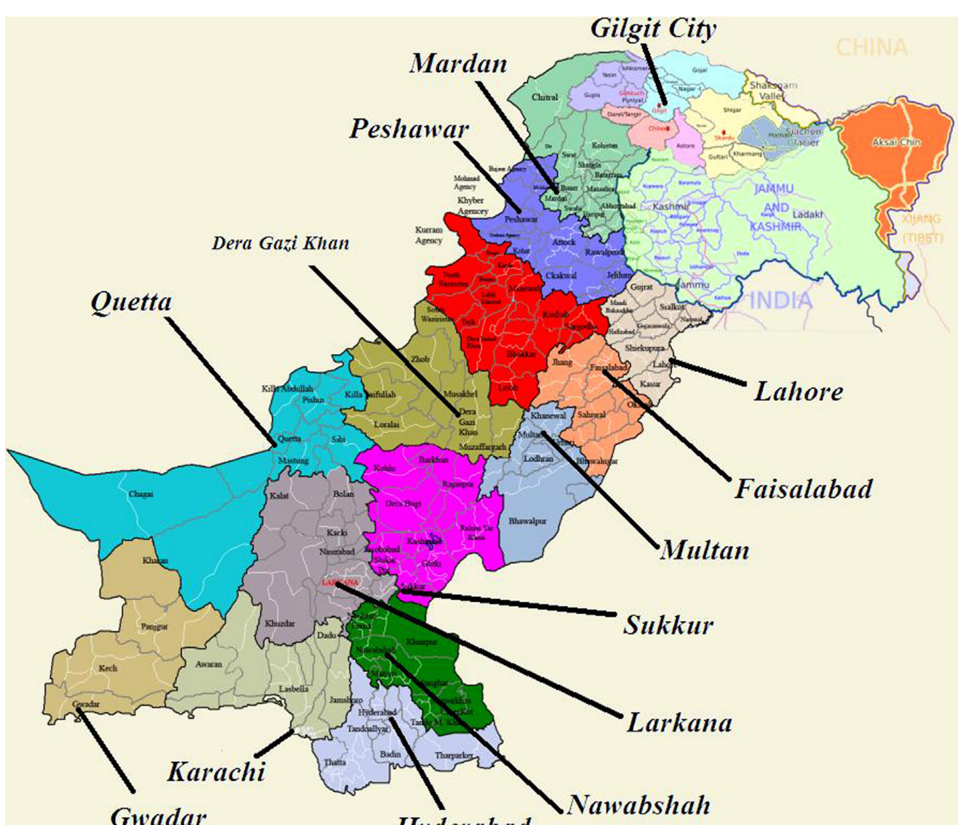


Fig. 1. Geographic Map of Pakistan.

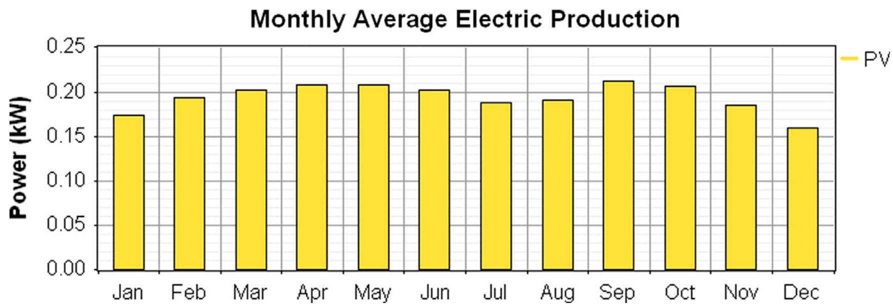


Fig. 4. Energy production of solar cell in Lahore.

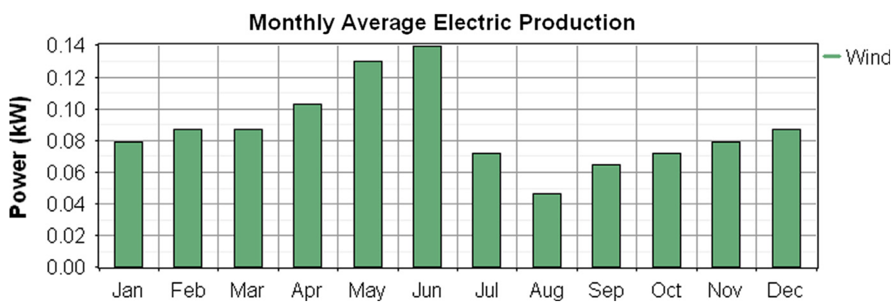


Fig. 5. Energy production of wind turbine in Lahore.

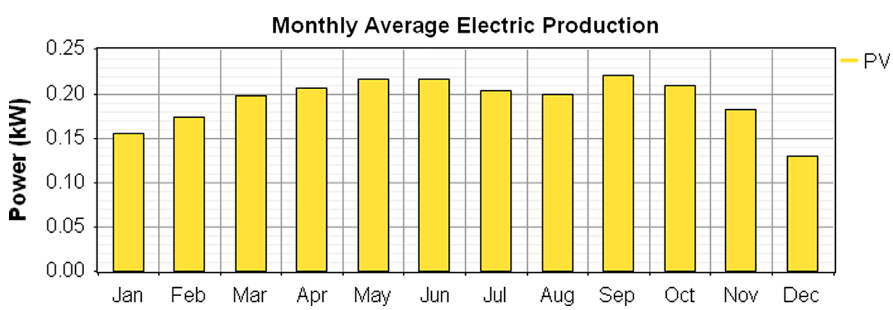


Fig. 6. Energy production of solar cell in Faisalabad.

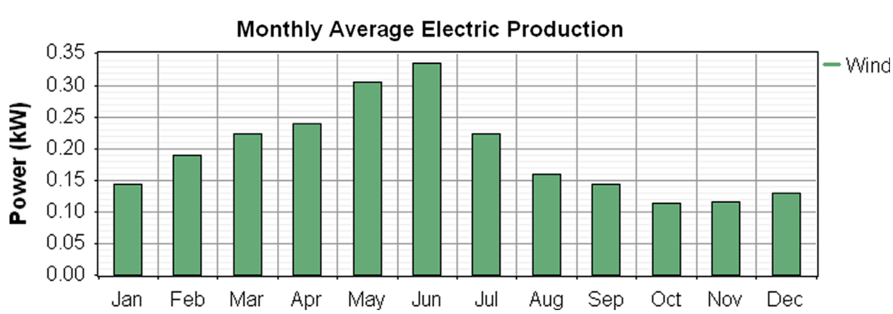


Fig. 7. Energy production of wind turbine in Faisalabad.

natural gas that the increase in generation cost and pollution. Therefore cost of electricity exposed to fluctuation in global oil prices. Under the Regulation of Generation, Transmission and Distribution of Electric Power Act in 1997 National Electric Power Regulatory Authority (NEPRA) was established. It is responsible for issuing the licenses for generation of electricity and monitors the performance standards of transmission and distribution of electric power. It also determines the tariff rates of electric power in the entire country.

The real problem is that the liability for the operation of the country's power sector and determining national energy policy is shared among

- Ministry of water and power and 19 subsidiary agency.
- Energy wing of ministry of planning and development.
- Ministry of petroleum and natural resources and 16 subsidiary agencies.

Three other ministries and seven agencies are also involved in energy sector that complicate the picture. In addition, the conflict of interest among these institutions and agencies obstructs the energy saving measures introduced by the government. It is understood that with the conflict and lack of coordination in institutions existing infrastructure has not the ability to compete with energy shortfall and progress the condition of electricity.

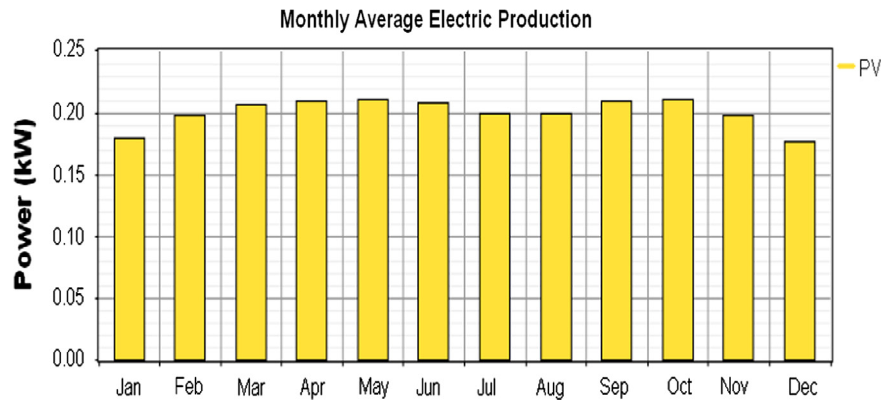


Fig. 8. Energy production of solar cell in Sialkot.

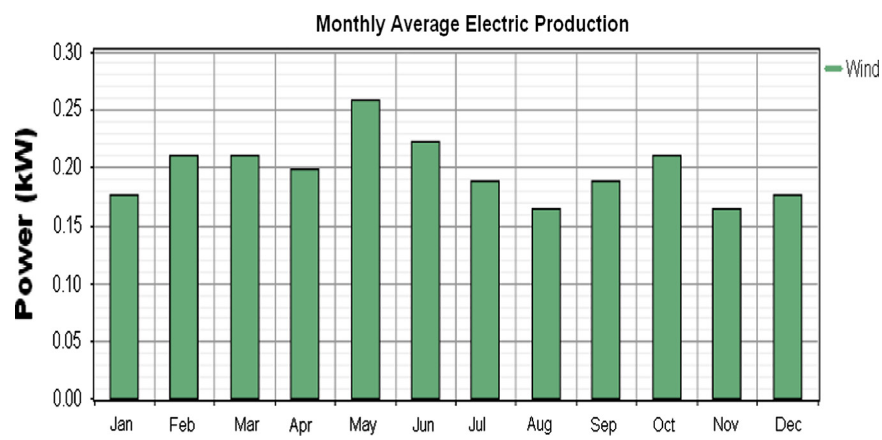


Fig. 9. Energy production of wind turbine in Sialkot.

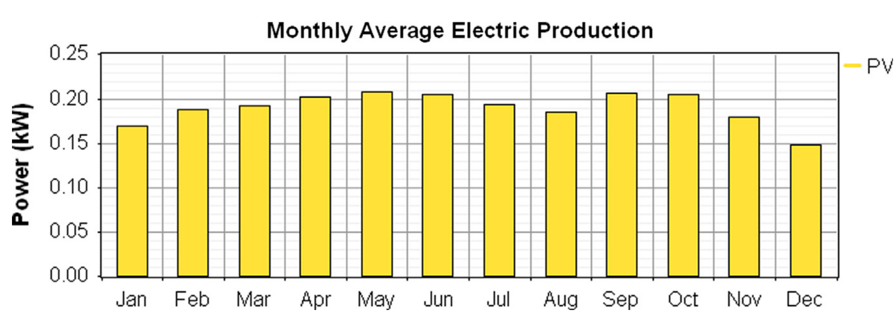


Fig. 10. Energy production of solar cell in Islamabad.

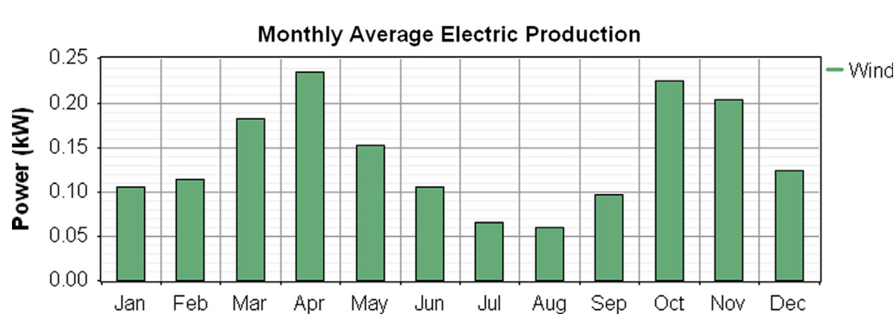


Fig. 11. Energy production of wind turbine in Islamabad.

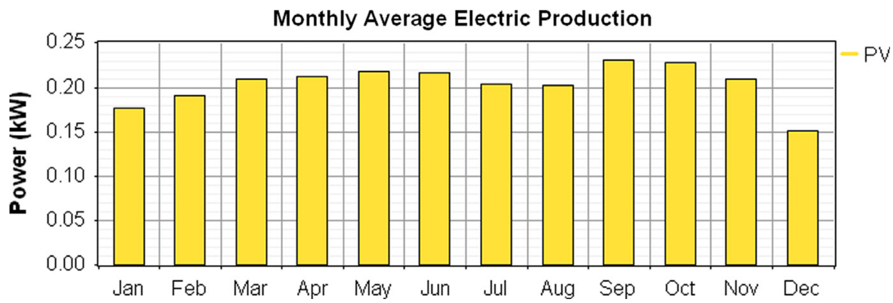


Fig. 12. Energy production of solar cell in Gilgit.

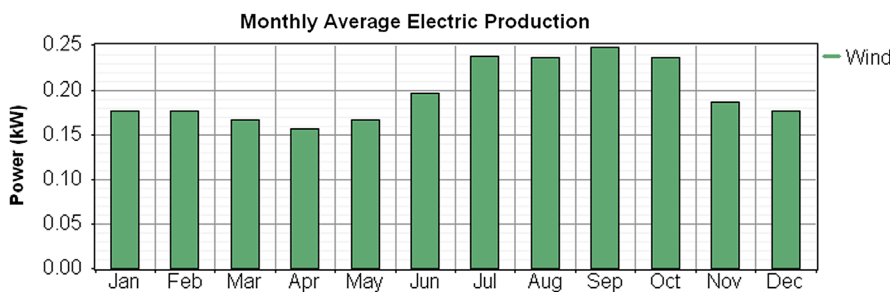


Fig. 13. Energy production of wind turbine in Gilgit.

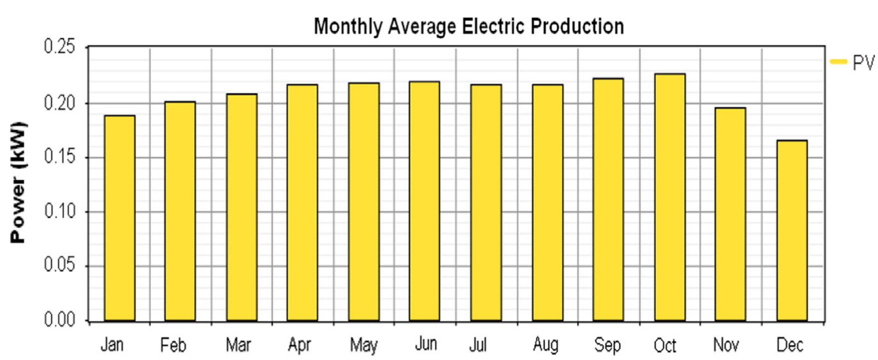


Fig. 14. Energy production of solar cell in Karachi.

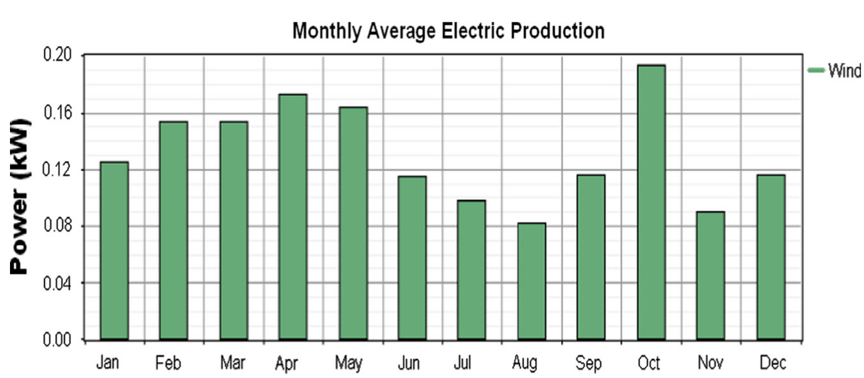


Fig. 15. Energy production of wind turbine in Karachi.

3.1. *Current energy conditions*

The difference in energy generation and demand was 2645 MW in the year 2007 which increased to 6151 MW in the year 2011. Electricity shortage also tends to increase even in the winter season at the lowest level in reservoirs of the dams and demand of natural gas in domestic level [4]. The main reasons for energy supply and demands are:

- Seasonal (in summer) instability in the capacity of hydropower resources such as Terbela (3470 MW) and Mangla (1000 MW).
- Thermal power plants have a shortage of gas supply in winters.

- Irregular supply of furnace oil to thermal power plants.
- Scheduled maintenance and inspection of power plants.

In addition the distribution companies have old infrastructure and they have not been operated efficiently. There are energy losses due to aging infrastructure and excess load on transmission lines and transformers. Transmission and distribution losses consumed up to 20% of the total electricity throughout the distribution sector in year 2010 [5]. The energy loss in the Lahore region was 18.5% in June 2011. And an average line loss in the year of 2011 is 12.58% [13]. Government paid the Rs. 120 billion to PEPCO to clear the remaining disbursement in May 2011. But this amount does not resolve the issue convincingly; the overall circular debt was reached to Rs. 251 billion by the end of June 2011 [5].

3.2. Steps taken

To address the electricity shortage problem new power plants and construction of dams must be completed. In this regard Private sector added new capacity of 1602 MW in which 852 is based on gas, during the years 2008 to 2012. Gas of 1571 mmcfd is required by the gas depended generation sector as the capacity of this sector is increased to 7221 MW. However, gas supply to the generation sector in the year 2010 was falling to 1005 mmcfd, and still in the year 2013 it is unable to enhance significantly. In addition, furnace oil for production also required by new power plants, so the import of furnace oil is compulsory to meet their requirements. On April 2012 supplies of furnace oil from other countries were distressed, as the circular debt receivables was attained unsustainable levels for Oil marketing companies (OMCs). For thermal generation supply of furnace oil was reduced to 30% of the daily requirement [5].

Table 1 shows the energy consumption in different sectors of Pakistan. Domestic and Agriculture user cumulatively utilizes 60% of the overall energy. Demand from theses two sectors is seasonally dependent and increased in summer season. Demand of electricity was 11,081 MW in November 2010 which dramatically increases up to 18,511 MW in June 2011 with the difference of 7400 MW. The aim of this paper is to partially fulfill the demand of these sectors, which will definitely have a greater impact on the entire energy system. Steps taken by the government in regard of renewable energies are very negligible. In year 2013, only the chief minister of Punjab distributed 15 W solar panels among the students, which definitely cannot be feasible and support the severe energy crises.

Government of Punjab is working seriously on solar energy to resolve the load shedding issue up to maximum level (Table 2). In this regard, energy department of Punjab has established Quid-e-Azam solar power company (QA Solar) to develop large scale power projects in the province of Punjab. A project of 2000 MW was signed by the Asian development bank and government of Punjab. That project is based on public–private partnership and will be completed in the year 2015. Chinese and Turkish companies are also interested to invest in energy sector of Pakistan. China power investment crop (CPI Group) has shown keen interest in four power projects. Projects of 660 MW and 300 MW will be installed in Lahore and Bahawalpur respectively.

Table 1
Energy consumption in various sectors.
Source: Ministry of water and power [13].

Sector	Punjab	Sindh	KPK	AJK	Baluchistan	Grand total
Agriculture	6.8	1.2	0.5	0.0	4.1	13.0
Bulk supply	3.5	1.7	0.7	0.0	0.1	5.9
Domestic	28.0	9.3	7.3	0.8	0.6	46.1
Industry	18.3	6.1	1.9	0.1	0.2	26.7
Commercial	4.7	2.0	0.7	0.1	0.1	7.5
Other	0.3	0.3	0.0	0.1	0.0	0.7
Total	**61.7**	**20.6**	**11.1**	**1.1**	**5.5**	**74,349 GWh**

Table 2
installed unit and their capacities.
Source: PCRET.

Installed	Units	Total capacity
Micro-hydel	538	7.8 MW
Wind turbine	155	161 kW
Solar PV	300	100 kW
Biogas plant	4000	1800 M^3/Day
Solar dryer	21	5230 kg/Day Fruit

4. Solar energy

Geologically Pakistan is located in the region of highest solar isolation in the world. Most of the areas receive high solar radiation intensities in a long season of summer [2,6]. The potential of solar and renewable energy was extensively studied by the researcher in Pakistan. But unfortunatelydue to lack of good policies major part of up to 38% is produced by expensive oil. And renewable energies are not taken into account seriously. In the early nineteen solar cells with the capacity of 440 W was installed for village electrification in different areas but they became un-operational very soon due to lack of interest and follow up. In May 2001 Pakistan council of renewable energy technologies (PCRE) was established [11]. For making the PCRE the National Institute of Silicon Technology (NIST) and Pakistan Council of Appropriate Technology (PCAT) were in alliance together. But progress of this council is very slow and still any mega project of solar energy is not initiated. Generation of electricity through solar cell is extremely small in amount [3]. But with the high index of light we can increase the PV capacity which is 100 kW at this time. Solar energy would be an aid during the load shedding and provide back up for a longer time.

The energy crisis has paralyzed the economy of Pakistan. The Circular debt reached to Rs. 251 billion in June 2011; however there is a bundle of issues behind the energy crisis. Most of the generation of electricity is oil depended, while oil and gas companies cut the supply to generation companies due to non-payments, that make the load shedding situation more critical. Oil prices are going high which directly raise the unit price of electricity. Above all, inadequate tariff price levels affect the production industry and the economy. Furthermore, IPPs are working under take-or-pay agreement so the Government is obliged to pay a prescribed amount based on the agreed minimum level of power sale, even if oil supply is halted and the Government takes less power than the agreed minimum. In conclusion, by developing the solar power we can get rid of such type agreements and our tariff will not be affected by oil prices.

5. Our methodology

For the simulation of the results MAT Lab, HOMER and RTScreen are used; and for correct location and index of lights at required location we accessed the NASA Database. Speed of wind and the intensity of the light in each month is computed and plotted against the 1 kW PV and Wind turbines at specific locations. Results generated by the wind turbine and PV are

Table 3
Comparison of energy sources.

	Solar Panel (1 kVA)	Gasoline Generator (1 kVA)	Wind Turbine (1 kVA)
Price	Rs. 65,000	Rs. 110,00	Rs. 120,000
Fuel consumption	Nil	RS. 114/h	Nil
Life span	25 years	4–5 years	10–15 years
Maintenance	Nil	Rs. 6.5/h	Rs. 3.5/h
Carbon monoxide	Nil	6.5 g/Liter	Nil
Un-burned hydro-carbon	Nil	0.72 g/Liter	Nil
Nitrogen oxides	Nil	58 g/Liter	Nil

compared and then found the best suitable resource (Table 3). Results are shown in terms of monthly average electricity production (MAEP). Electricity produced by solar cells and wind turbine in each month is shown by figures in yellow and green color charts respectively.

We start our work from the Lahore city. It is an ancient city and the provincial capital of Punjab. The population of this commercial city is 90 million. The largest numbers of industrial and domestic consumer are residing in this region of LESCO.

Simulation results show that the Lahore is suitable for solar energy; monthly average production is higher with a solar cell.

Faisalabad is known as the Manchester of Pakistan. It is famous due to its textile industry. More than 65% of the textile export market of Pakistan situated in Faisalabad. The textile industry forms 58% of the total exports from Pakistan. So Faisalabad has more than 40% share of the total exports from Pakistan. Energy is crying need of this city. Load shedding makes conditions of this city miserable. We selected this city to choose the best available renewable resources.

In Faisalabad city the wind energy is only suitable during the month of June. But the solar energy gives better output throughout the year. These resources can give a significant aid to run the industry smoothly.

The 3rd city we choose is the Sialkot. It is located between 32°30′ North and 74°31′ East. Sialkot is the economic hub of Punjab, Pakistan. It is the fourth largest industrial city. In year 2012 the Per Capita Income of Sialkot was $2800, which was $2400 and $2100 in 2010 and 2008 respectively. Sialkot is worldwide famous due to surgical instruments and sports goods.

Islamabad is the capital of Pakistan located at 33.43°N 73.04°E. It is adjacent to an ancient city Rawalpindi. The climate of both the cities is almost the same. Its area is 906 km^2 with the population density of 2171/km^2. The condition of electricity is also not in good condition. It also has an industrial zone in sectors I-9 and I-10. Being an important lavish city and capital of Pakistan we implement the simulations and calculate the results.

Gilgit is the capital of the province of the Gilgit–Baltistan located at 35.9167°N and 74.3000°E. It is famous due to silk road and touring. Tourists from all around the world come to visit this city every year. Most of the remote areas do not connect to the energy grid. By giving the energy to these areas we can cut the load and also promote the tourism. Which directly influences the economy.

In simulation results (Fig. 13) we found that the wind energy is the most suitable source for generation of electrical energy. Solar energy can also contribute a lot. By using both resources we can get a better output energy.

Karachi located at 24.8508°N and 67.0181°E and known as “City of Light”. It is the capital of Sind province and economic hub of Pakistan. Karachi Export Processing Zone, SITE, and Korangi are the largest populated area with industrial zones. Bin Qasim, Northern Bypass Industrial Zone, and North Karachi are also well established industrial areas. It is important because of the sea port and called as revenue engine. Karachi produces 25% of the GDP of Pakistan and about 42% of value added in large scale manufacturing. Karachi Electric Supply company (KESC) has a shortage of 412 MW this was the most energy demanding area in the year 2013. 80 feeders in this city have high loss as up to 76% [13].

Results in Fig. 14 shows the monthly average production of energy by solar cell and Fig. 15 shows the energy produced by the wind energy. Almost in 5 months of a year we can get benefit from the wind energy in the coastal areas of Karachi. However solar cell also produces a high amount of energy throughout the year. We can utilize both sources to run the revenue engine of Pakistan.

Load shedding in urban areas is 8–10 hours while in rural areas it is too much higher and ranged 12–18 hours in a day. As the energy demands in the suburbs and rural areas are not high. More than 65% population of Pakistan is related to agriculture and live in rural areas, so we can easily fulfill their energy demands through solar energy. Renewable energies can give relief up to the significant level in hot summers. But we cannot be depended on renewable energies due to their intermittent nature. But we have no any other suitable, economical and locally based solution to combat the supply demand gap of electricity.

6. Conclusions

Multidimensional policies are required to control the energy crisis and achieve high economic growth rates. Energy sector must be the top priority in these policies. First of all the conflict among the monitoring agencies should be resolved. We must develop alternative energy sources in order to control the energy crisis. The importance of energy supply and demand is significant not only for the economic prosperity but also for the current and future generations. Our survey calculated and found solar energy better than wind energy in major cities of Pakistan. In overall conditions the wind turbines are not feasible and produced sufficient energy in most of the cities. Wind turbines are only applicable in coastal and desert areas of Baluchistan. Our simulations show highest 0.22 kW and lowest 0.15 per day from a 1 kW solar panel in Pakistan. On an average we can get 0.17 in the entire country. This can significantly reduce the burden on the energy system and help in load shedding timing. This energy is sufficient to facilitate the domestic user which is consuming 46% of current energy produced. In the future after the development of hydropower or nuclear power plants, these solar energies can be performed as prompt available substitutes [8]. It is clear that conventional energy resources are significant and renewable energy (for a long term) cannot be used as an alternative to them, but these alternative resources can serve the energy requirements of Pakistan to a considerable level.

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